

once were directly measured, and the average value (from thirty measurements) was 99.25 m. From this the velocity of sound in free air = 335.19 m. Reducing the value to that for dry air at zero the number obtained is 331.57 m. This lies about midway between Regnault's value (330.7) and that of Moll and Van Beck (332.26).

At a recent meeting of the Berlin Geographical Society, Prof. Karsten, of Kiel, read an interesting account of the activity of the Commission established in Schleswig-Holstein, which has for its object the exact and minute investigation of the climatological, physical, and chemical conditions of the Baltic and the German Ocean, as well as of the influence which these conditions exercise upon organic life. The commission has established a large number of stations for making observations of the currents existing in these seas, in order to obtain data for the understanding of the general laws governing marine currents. With regard to animal life, the commission has up to the present confined its labours to the most important inhabitant of the two seas, the common herring, and it has succeeded in determining with certainty the few zoological varieties of this fish, as well as in finding its spawning places, and as a result, the artificial cultivation of herrings has already been set on foot. The commission will now devote its attention to other species of fish.

A GERMAN Viticultural Society has just been formed at Cassel. For the present the Society intends to take up two important matters, viz., (1) discovering the best method for the destruction of phylloxera, and (2) the suppression of the secret manufacture of wines by artificial means.

IN NATURE (vol. xvii. p. 372) an account is given of the difficulty met with in Australia in getting bees to work after a few years. A correspondent calls attention to the fact that a similar difficulty occurred in California, where it has been obviated by a systematic abstraction of the honey as the bees collected it. If this were tried in Australia it might possibly meet the difficulty.

In a recent communication to the Belgian Academy on digestion in insects, M. Plateau, after a careful examination of forty individuals of various types retires from his former position that the digestive juices (in the normal state) are *never acid*. In insects which feed wholly or partly on animal matters, they are slightly acid. He will not, however, concede a constant acidity for all insects (which some naturalists affirm); and in reply to the objection based on the characteristic acidity of the gastric juice of vertebrates, he contends that the digestive liquid in articulates, insects, myriapoda, arachnida, and crustacea is not analogous to that juice, but rather to the pancreatic juice; the acidity is an accessory character and not the sign of a physiological property. The ferment present is evidently something quite different from the gastric pepsine of vertebrates. Thus, a very little hydrochloric acid, so far from promoting its action, retards or arrests it.

A NEW method, said to be more accurate in its results than that of Helmholtz, for determining the tones of the mouth-cavity which correspond to the vowels, is recommended by M. Auerbach in a recent number of the *Annalen der Physik*. It is based on percussion. Having made a long inspiration, you bring the mouth into the position corresponding to the particular vowel, and then strike the larynx after the manner of physicians, i.e., place the middle finger of one hand firmly on it, and strike it with that of the other hand. A comparatively distinct tone is then heard, which varies with the position of the mouth, but for a given position is always the same. The effects are perceived more distinctly if the ears are previously stopped with wax. M. Auerbach describes results of observation by this method.

MR. A. W. BENNETT (Lecturer on Botany, St. Thomas's Hospital, London, S.E.) requests us to state that he is engaged on an introductory handbook of Cryptogamic Botany, to be pub-

lished in the International Scientific Series, and that he will be extremely glad of any recent original memoirs, English or Foreign, bearing on any branch of the subject which the authors may incline to send him.

AN International Congress of Botany and Horticulture will be held in Paris on August 16 and following days, under the auspices of the Botanical Society and the Central Horticultural Society of France, in the rooms of the latter Society, 84, rue de Grenelle. A programme of subjects, botanical and horticultural, is announced, on which papers are especially invited, as well as the exhibition of illustrative specimens, collections, and apparatus. One of these subjects is the establishing and fitting up of botanical laboratories. The attendance and co-operation of foreign botanists are cordially invited.

In the year 1877 no less than 8,000 new publications appeared in Italy. Amongst these there were 5,743 new books (1876 : 4,323), 1,880 pamphlets (1876 : 1,524), and 194 new journals (1876 : 256).

THE additions to the Zoological Society's Gardens during the past week include two Common Marmosets (*Hapale jacchus*) from South-East Brazil, presented by Mr. R. Donaldson; a Three-striped Paradoxure (*Paradoxurus trivirgatus*) from India, presented by Capt. Dalrymple; a Secretary Vulture (*Serpentarius reptilivorus*) from South Africa, presented by Messrs. W. Rigg and J. Curtis; a Green Glossy Starling (*Lamprocolius chalybeus*) from North-East Africa, a White-eared Bulbul (*Pycnonotus leucotis*) from India, a Californian Quail (*Callipepla californica*) from California, presented by Mrs. Arabin, F.Z.S.; a Common Kestrel (*Tinnunculus alaudarius*), European, presented by Mr. A. Blumenthal; a Lion (*Felis leo*) from Africa, a Variegated Sheldrake (*Tadorna variegata*) from New Zealand, received in exchange; two Common Swans (*Cygnus olor*), European, deposited; three Black Swans (*Cygnus atratus*), bred in the Gardens; a Zebu (*Bos indicus*), two Common Badgers (*Meles taxus*), born in the Gardens.

THE ANALOGIES OF PLANT AND ANIMAL LIFE¹

II.

WE may find a kind of analogy for these cases of contradictory action—for they really strike one as contradictory.

The chameleon and the frog are both affected in a peculiar manner by light; they both change colour in accordance with variations in the intensity of the light. Moreover, the change of colour is produced by the same mechanism in the two cases; by a kind of contraction and expansion of certain coloured cells in their skin. But the curious fact is that chameleons² become darker in sunshine, while frogs³ become pale in sunshine and darker in darkness. No doubt both these changes are in some way serviceable to the frog and the chameleon, and we may suppose that the whole phenomenon is really analogous to the opposite effects of light which occur in plants.

To quit the paths of science for those of another region of "Wonderland," it has been pointed out by Mr. Lewis Carroll that dogs wag their tails when they are pleased, whereas cats do so when angry. Seriously the principle is the same—given that emotion produces disturbance of the tail, it will depend on the surrounding circumstances in which the creatures live as to whether a given emotion shall produce a wagging or a rigid tail.

Let us once more consider what needs will arise in the life of an animal, and then see how the same needs are supplied by plants. An animal needs to be alert to changes going on in the world around it; it needs delicate sense-organs to perceive the approach of enemies or the whereabouts of its food. In fact it is evident that to prosper in the varying conditions of life an animal must be sensitive to these changes. By sensitiveness one

¹ A Lecture delivered at the London Institution on March 11 by Francis Darwin, M.B. Continued from p. 307.

² Brücke, *Wien. Denkschrift*, 1851; v. Bedriaga, "Die Entstehung der Farben bei den Eidechsen," 1874.

³ Lister, Cutaneous Pigmentary System of the Frog. (*Phil. Trans.*, 1858; v. Wittich, Müller's *Archiv*, 1854.)

means that an animal must be capable of being affected by changes which, considered as mere physical agents, are insignificant. A fly living in the same room with an active-minded boy will depend for its safety on its power of rapidly appreciating the approaching shadow of the boy's hand. Now the changes produced in the arrangement of forces in the universe are not perceptibly affected by this shadow—it is utterly insignificant—yet what a violent effect it has on the fly. It is because the nervous system of the fly possesses the property of magnifying external changes so that apparently slight disturbance causes large results.

This power of being strongly affected by apparently slight changes is a very important character of living matter. The processes which occur within the fly have been likened to the explosion of a pistol, the force used in moving the trigger being utterly insignificant when compared with the result produced. I do not mean that this exploding power is a distinguishing mark of living matter, but it certainly is a well marked feature. Besides the power of magnifying or intensifying external changes, which we have described as the exploding power of irritable tissue, there is another, the power possessed by nerves of transmitting a stimulus wave from one part to another. We will first look for this transmitting power as it exists in plants.

The leaf of the sundew, or *Drosera*, consists of a shallow, slightly saucer-shaped disc covered over with short glands, and fringed all round with projecting tentacles which also terminate in glands. The glands secrete a sticky fluid, which hangs in drops on them, hence the name of sundew, because the leaves seem to be covered with dew in sunshine, when other plants are dry. Insects are caught by the sticky secretion, and are also embraced and held fast by the outer tentacles, which possess the power of moving. When the insect has been killed by being drowned in the sticky secretion, it is digested by the acid juice poured out by the glands and subsequently absorbed.

The external or movable tentacles may be made to bend inwards, either by insects alighting on the centre of the disc of the leaf, or on the sticky glands of the tentacles themselves. In the first case, when an insect is caught on the middle of the leaf, and the external tentacles bend in and surround it, we have a true transmission of stimulus, a message sent, like a message is sent along a nerve. The insect may be struggling to free itself, and will probably succeed in doing so, unless the external tentacles give their help. The external tentacles can be made to bend not only by insects or other objects placed on the centre of the leaf, but also by anything placed on the gland at the end of the tentacle itself. In this case the meaning of the movement is equally obvious. If a gnat or fly lights on one of the external glands, it will probably escape, unless carried to the centre of the leaf, where it will be also held by the small sticky glands. Here also there is a true transmission of stimulus. The message has to be sent from the gland at the top to the place where the tentacle bends; a message is sent from the gland to the bending part of the tentacle, just as a message goes through nerve tissue from our skins to our muscle.

In this case the tentacle always carries the fly it has caught to the actual centre of the leaf. But if a fly has been caught by the disc of the leaf, and not quite in the centre, then the messages are sent in accordance with the position of the fly, and all those tentacles within reach move to the point of irritation with marvellous precision. This transmission of messages is all the more wonderful, because, as far as our powers of observation go, there is no special structure to convey the stimulus. It is true that waves of stimulation do travel with special facility along the fibro-vascular bundles, or what are usually called the veins of the leaf. But in this case, where tentacles converge to a given point in the disc of the leaf, this mode of transmission is impossible, because the veins are few in number, and could not cause so nice an adaptation of movements. Moreover, stimuli can travel across a leaf of *Drosera* after the vascular bundles have been cut through.¹ So that we have the wonderful fact of a wave of stimulation travelling with great accuracy transversely through a number of cells with absolutely no structure like nerve-fibre to guide the course in which the stimulus-wave shall flow.

One other curious phenomenon may be alluded to as showing the extraordinary power of stimulus-transmission. If a piece of meat is placed on an external tentacle, the gland on which it rests sends forth an acid secretion; and if a piece of meat is

placed on the centre of the leaf, the tentacles, as before said, bend in and ultimately touch it; but if the external glands are tested with litmus paper before they reach the meat in the centre, they will be found to be covered with acid secretion, proving that not only had a message been sent to the moving part of the tentacle, but also to the secreting cells in the gland.

One might find a parallel to this in the action of the human salivary glands. The gland nerves may be excited either by the stimulus of food placed in the mouth, or by the voluntary action of the muscles of mastication. Here the saliva is poured out, although there is no food to act on, just as the *Drosera*-gland secretes during the movement of the tentacle before there is anything for its secretion to digest.

Having briefly considered the transmission of stimulus-waves as shown in *Drosera* I will pass on to consider what manifestations may be found of the other general property of nerve tissue, the property which I have called exploding power. It is chiefly manifested in *Drosera* by the extreme sensitiveness of the glands on the external tentacles. It is found not to be necessary to place meat or insects on the gland, but that bits of glass, wood, paper, or anything will excite them. Smaller and smaller atoms were tried and still the glands were found to be sensitive to their presence.² At last a minute piece of a human hair, about one-hundredth of an inch in length, and weighing just over $\frac{1}{100000}$ of a grain, was placed on the gland of a tentacle and it caused unmistakable movement. The case is yet more wonderful than it sounds, because the piece of hair must be partly supported by the thick drop of secretion on the gland, so that it is probably no exaggeration to say that the gland can perceive a weight of one-millionth of a grain. This degree of sensitiveness is truly astonishing, it seems to us more like the sense of smell than that of touch, for to our most delicate tactile organ, the tongue, such atoms are quite imperceptible.

The power which *Drosera* has of perceiving the presence of ammonia is perhaps still more astonishing. A solution of phosphate of ammonia in pure distilled water in the proportion of one part to over two million of water, caused inflection of tentacles.³ One may form an idea of this result by making a solution of a single grain of the phosphate and thirty gallons of distilled water, and then finding out that it is not pure water. Considering the water-supply which we at present enjoy, we may well be grateful that our senses are duller than those of a sundew.

As examples of simple sensitiveness these facts are sufficiently striking, but the powers of discriminating between different kinds of stimuli are equally curious. The tentacles having proved so extraordinarily sensitive to light bodies resting on them, one would expect that the slightest touch would make them bend. But it is not so; a single rapid touch, though it may be violent enough to bend the whole tentacle, does not cause inflection. The meaning of this is clear, for in windy weather the glands must be often touched by waving blades of grass, and it would be a useless labour to the plant if it had to bend and unbend its tentacles every time it was touched. It is not excited except by prolonged pressures or quickly repeated touches. This is also quite intelligible, for when an insect is caught on the sticky secretion of the gland it will give a somewhat prolonged pressure, or a number of kicks to the sensitive gland, unless indeed it flies away after a single struggle, and in that case the tentacle will be also saved from uselessly bending.

In another carnivorous plant, *Dionæa*, the specialisation of sensitiveness is exactly the reverse; thick and comparatively heavy bits of hair can be cautiously placed on the sensitive organs without causing any movement, but the delicate blow received from a cotton thread swinging against the hair causes the leaf to close.³ *Dionæa* catches its prey by snapping on it like a rat-trap—there is no sticky secretion to retain the insect as in *Drosera* till the slowly moving tentacles can close on it. Its only chance of catching an insect is to close instantly on the slightest touch. The specialisation of sensitiveness in *Dionæa* is therefore just what it requires to perfect its method of capture.

In describing the sensitiveness of *Drosera* and *Dionæa* I wish rather to insist on a wide and general similarity to the action of nerves. There may be said to be an analogy between the specialisation of extreme sensitiveness in *Drosera* and *Dionæa* and the nervous tissues of animals, because these properties play the same part in the economy of the plant that is supplied through some kind of nerve machinery in the higher animals. Closer analogies could be pointed out. There are, for instance, the

¹ See Batalin, "Flora," 1877, who has correctly pointed out the importance of the fibro-vascular bundles as conveying stimulus-waves.

² "Insectivorous Plants," p. 32.

³ "Insectivorous Plants," p. 170.

³ "Insectivorous Plants," p. 289.

well-known researches of Dr. Burdon Sanderson, in which he compares the electrical disturbances which occur in the leaf of *Dionaea* to those which take place in nerve and muscle. Again Mr. Romanes has, in a recent lecture in this place, compared the peculiar sensitiveness of *Drosera* to repeated touches with the phenomenon known in animal physiology as the summation of stimuli. But I have merely sought to show that we find in *Drosera* a power of conduction of stimuli, an extreme sensitiveness to minute disturbances, and a power of discriminating between different kinds of stimuli which we are accustomed to associate with nervous action. To establish this analogy I believe that the examples already mentioned may suffice.

We will now inquire whether among plants anything similar to memory or habit, as it exists among animals, may be found.

The most fruitful ground for this inquiry will be the phenomenon known as the sleep of plants. The sleep of plants consists in the leaves taking up one position by day and another at night; the two positions for night and day following each other alternately. The common sensitive plant (*Mimosa*) is a good example of a sleeping plant. The leaf consists of a main stalk from which two or more secondary stalks branch off; and on these secondary stalks are borne a series of leaflets growing in pairs. The most marked character of the night or sleeping position is that these leaflets, instead of being spread out flat as they are in the day, rise up and meet together, touching each other by their upper surfaces. At the same time the secondary stalks approach each other and ultimately bring the rows of closed-up leaflets (two rows on each stalk) into contact. Besides this well-marked change the main stalk alters its position. In the afternoon it sinks rapidly, and in the evening it begins to rise, and goes on rising all night, and does not begin to sink until daylight. From that time it sinks again till evening, when it again rises, and so on for every day and night. In reality the movement is more complicated, but the essential features are as I have described them.

In comparing the sleep of plants with anything that occurs in animal physiology, we must first give up the idea of there being any resemblance between this phenomenon and the sleep of animals. In animals, sleep is not necessarily connected with the alternation of light and darkness, with day and night. We can imagine an animal which by always keeping its nutrition at an equal level with its waste would require no period of rest. The heart which beats day and night shows us that continuous work may go on side by side with continuous nutrition.¹ Mr. Herbert Spencer has suggested that since most animals are unable to lead a life of even ordinary activity during the night because of the darkness, therefore it answers best to lead an extremely active life in day when they can see, and recover the waste of tissue by complete rest at night. On the other hand, certain animals find it more to their profit to sleep in the day and rest at night. But there is nothing of this kind in plants; their sleep movements are not connected with resting. Although the leaflets close up, yet the main stalk is at work all the night through.² Moreover, owing to the closing up of the secondary stalks of the leaf, the length of the whole organ is increased, and therefore the work done by the main stalk is also increased. So that, far from resting at night, the main stalk is actually doing more work than in the day. Besides this, instead of being more or less insensible, as a sleeping animal is, the primary petiole of the *Mimosa* remains fully sensitive at night, and displays the same property which it shows by day, viz., that of falling suddenly through a large angle on its irritable joint being touched. Besides these points of difference, there is the important distinction that the movements of sleeping plants are strictly governed by light and darkness without any reference to other circumstances.

In Norway,³ in the region of continual day, the sensitive plant remains continually in the daylight position—although no animals probably remain continually awake.

There is one—but only a fanciful resemblance—between the sleeping plants and animals, namely, that both have the power of dreaming. I have been sitting quietly in the hot-house at night waiting to make an observation at a given hour, when suddenly the leaf of a sensitive plant has been seen to drop rapidly to its fullest extent and slowly rise to its old position. Now in this action the plant is behaving exactly as if it had been touched on its sensitive joint; thus some internal process produces the same impression on the plant as a real external stimulus. In the same

way a dog dreaming by the fire will yelp and move his legs as if he were hunting a real instead of an imaginary rabbit.⁴

I said that in the regions of perpetual light the sensitive plant remains constantly in the day position. We might fairly expect, therefore, that we should be able to produce the same effect by artificial light constantly maintained. This experiment has, in fact, been made by A. de Candolle,⁵ Pfeffer, and others with perfect success. But before the leaves come to rest a remarkable thing takes place. In spite of the continuous illumination, the sleeping movements are executed for a few days exactly as if the plant were still exposed to the alternation of day and night. The plant wakes in the morning at the right time and goes to sleep in the evening; the only difference between these movements and those of a plant under ordinary circumstances is that under constant illumination the movements become gradually smaller and smaller, until at last they cease altogether. When the plant has been brought to rest it can be made to sleep and wake by artificial alternations of darkness and light. This fact seems to me extremely remarkable, and one which, in the domain of animal physiology, can only be paralleled by facts connected with habit. The following case is given me by a friend and is probably a common experience with many people:—Having to be at work at a certain time every day, he has to get up at an early hour, and wakes with great regularity at the proper time. When he goes away for his holiday he continues for a time waking at the proper hour to go to work, but at last the body breaks through the habit, and learns to accommodate itself to holiday hours.

It seems to me that this case may fairly be likened to that of the sensitive plant in constant illumination. There is the same continuance of the periodic movement on the first removal of a stimulus, and the same gradual loss of periodicity consequent on the continued absence of the stimulus.

From this kind of habitual action there is but a small step to those actions in which we say that memory comes into play. Dr. Carpenter⁶ relates the case of a boy who, in consequence of an injury to his brain, never acquired the power of speech or of recognising in any way the minds of other people. In spite of this mental incapacity he had an extraordinary sense of order or regularity. Thus although he disliked personal interference, his hair having been one day cut at ten minutes past eleven, the next day and every following day he presented himself at ten minutes past eleven, as if by fate, and brought comb, towel, and scissors, and it was necessary to cut a snip of hair before he would be satisfied. Yet he had no knowledge whatever of clocks or watches, and was no less minutely punctual when placed beyond the reach of these aids.

It is hard to say whether this boy actually remembered at ten minutes past eleven that now was the time to have his hair cut, or whether it was an unconscious impulse that made him do so. But whether we call it habit or memory, there is the same knowledge of the lapse of time, the internal chronometry, as Dr. Carpenter calls it, which exists in the sensitive plant, and the same tendency to perform an action because it has been done previously. There is, in fact, hardly any distinction between habit and memory; if a man neglects to wind up his watch at night, he says that he forgot it, and this implies that memory normally impels him to wind it; but how little memory has to do with the process is proved by the fact that we have often to examine our watches again to see that they are wound up. It is the old problem of conscious and unconscious action. If a friend, in order to test our powers of self-control,⁷ moves his hand rapidly near the face, we cannot help winking, though we know he will not hurt us; and when we are breaking through a hedge or thicket, we close our eyes voluntarily to keep twigs out. Here are two actions performed with the same object by the same muscles under command of the same nerves, yet one is said to be directed by the will and the other by instinct, and a great distinction is drawn between them. It seems to me that the presence of what Mr. Lewes calls "thought consciousness" is not the crucial point, and that if it is allowed that the sensitive plant is subject to habit (and this cannot be denied), it must, in fact, possess the germ of what, as it occurs in man, forms the groundwork of all mental physiology.

I am far from wishing to make a paradoxical or exaggerated statement of this resemblance between the periodic movements of plants and memory of the human mind. But the groundwork

¹ Leaving out of the question the repose during diastole.

² In *Mimosa* at least.

³ Schübler, quoted by Pfeffer ("Die periodische Bewegungen der Blattorgane," 1875, p. 36).

⁴ This curious phenomenon was first observed by Millardet, who describes it as of rare occurrence. (Millardet, *loc. cit.*, p. 29.)

⁵ Quoted by Pfeffer ("Periodische Bewegungen," p. 31).

⁶ "Mental Physiology," p. 349.

⁷ See "Physiology of Common Life," vol. ii. p. 200.

of both phenomena seems to be the repetition of a series of acts, or the recalling of a series of impressions, in a certain order at a certain time, because they have been repeated in that order and at that time on many previous occasions.

I will mention one more fact in connection with the movements of *Mimosa*, in which the formation of habit is illustrated. Every one knows that a noise regularly repeated ceases to disturb us; that one becomes habituated to it, and almost ceases to hear it. A boy fast asleep inside an iron boiler while riveting is going on, is an example of this power of habituation. The same thing occurs with the Sensitive Plant. A single violent shake causes the main stalk to drop, and the leaflets to shut up; in a minute or two the leaf recovers, and will again react on being disturbed. In order to test the power of habituation, I fastened one end of a thread to the leaf of a sensitive plant, and the other to the pendulum of a metronome, and placed the plant just at such a distance from the instrument that it received a pull at every beat. The first shock caused the leaf to shut up, but after a few repetitions it became accustomed to it, and I had the curious sight of a highly-sensitive plant unaffected by a series of blows. In nature this power no doubt enables the plant to withstand the constant shaking of the wind.

In spite of the amount of time which has been spent on the study of sensitive and sleeping plants, no satisfactory explanation of the use which the movements are to the plant has ever been given. In the case of the carnivorous plants, we saw that the movements of plants may be offensive, and like the movements of animals in securing its prey. In the case of certain flowers which we will now consider, the movements are defensive, like the closing of a sea anemone. I shall describe these movements with a view to showing the existence of periodicity or habit, and some other general resemblances to animal physiology.

The crocus is perhaps the best example of a flower which opens and shuts in accordance with changes of external circumstances. The crocus is especially sensitive to changes of temperature. If a light index is fastened into one of the petals or divisions of the flower, very small movements are made visible, and in this way it has been shown that the crocus actually appreciates a difference of temperature of one degree Fahrenheit.¹ I have seen a crocus distinctly open when a hot coal was brought near it. The use of this power of movement is connected with the fertilisation of the flower. In the warm sunshine the flower opens wide, and the bees are soon hard at work, and carry pollen from one flower to another. If, now, a cloud hides the sun, the temperature falls, and the crocus begins to close, and by the time the sky has become overcast and the first drops of rain fall, the precious pollen is housed safe beneath the roof of petals. The crocus is warned of the coming danger by the shadow of the cloud just as the fly is warned by the shadow of the approaching hand. The crocus is sensitive to changes of light and darkness as well as to changes of temperature, and the sum of these influences alternately acting by night and day produce a periodic opening and shutting which resembles the periodic movement or sleep of the Sensitive Plant. Corresponding to the regular repetition of the stimulus of light and heat, an internal periodicity has arisen in the flower which shows itself in a curious manner. This phenomenon is best shown by certain flowers which are not so sensitive to temporary changes, but which open and close regularly by day and night. Raising the temperature in the evening does not produce nearly the same amount of divergence of the petals as a similar rise in the morning. With the white waterlily, *Oxalis rosea*, and some other flowers, the same thing is well seen.² If the flowers have been allowed to close at the natural hour in the evening it is hardly possible to perceive the least opening of the petals even when the temperature is raised from 50° to 82°. On the other hand a considerable lowering of temperature does not produce so much effect in the morning as it does towards evening. In all biological problems it is necessary to consider the internal condition of the organism quite as much as the other element, viz., the external condition. It is a familiar fact that similar external causes do not produce like results. A man may fall ill after exposure to wet and cold at different times of his life and the kind of illness may be very different. Once it may be rheumatic fever, another time pleurisy, or some other malady, so that in the case of the flowers which, under a given change of temperature, behave differently at different times of day, we see the variability in the internal condition or receptive

state of the organism exemplified, the most interesting fact being that the receptiveness varies not capriciously but with periodicity.

The same phenomenon may also be seen when the cycle is a yearly and not a daily one. A German physiologist has lately made a long and patient research on the yearly periodicity in the growth of buds.¹ The method consisted in ascertaining the weight of 100 cherry buds gathered at frequently repeated intervals throughout the year. In order to discover whether the growth of buds would be equally increased in rapidity at all times by a given increase of temperature, branches were cut and kept in a greenhouse at a temperature of 60 to 70 at various times of the year. This experiment showed that branches thus treated in the beginning of December were hardly at all hurried on in growth, while the rise of temperature at once produced energetic growth in buds in the middle of January. If this fact is to be classed with the very similar effects of temperature on the daily periodic changes in flowers—and I can hardly doubt that it ought to be so classed—a difficulty arises. The buds being new growths, have never experienced a previous winter or spring, so that the periodicity cannot originate in their tissues; it must, therefore, depend on some property common to all the branches, some periodicity common to the nutrition of the tree. Askenasy describes the case as the occurrence of some chemical change which goes on in the buds, rendering them sensitive to rise of temperature at a certain period. The case bears a resemblance to the hibernation of animals. Thus, Berthold² says that when the dormouse, *Myoxus avellanarius* first goes to sleep in the autumn, it can be partly awakened, and then sent into deep sleep by alternations of temperature, answering, like the crocus, to alternations of heat and cold; but when the winter sleep has fairly set in, no effect could be produced by raising the temperature,—just as the oxalis and water lily when once shut for the night could not be made to open.

I have no doubt that many closer analogies will some day be shown to exist between the behaviour of plants and animals, as regards nerve-physiology. The after-effect of stimuli seems to be represented in the movements of plants. If a stimulus is suddenly applied and then removed, the nerves acted on do not cease to be disturbed the instant the stimulus ceases. The molecular change, whatever it is, which goes on in the nerve, cannot leave off directly the stimulus ceases. The molecular action goes on like the vibration of a bell after it has been struck. When a wheel is turned round rapidly before our eyes the image of a new spoke strikes the retina before the image of the old one has died away, so that we cannot distinguish one from another. In the same way a burning stick whirled round looks like a circle of fire. This after effect of stimuli is represented in plants by heliotropism and geotropism. I have myself observed it in the latter. I took a young growing shoot and put it through a hole in a cork, so that it was firmly fixed into a bottle of water. I then put the bottle on its side in a vessel filled with wet sand, and fixed it firmly by piling wet sand over it. The shoot thus projected horizontally from the vessel of sand. It now began to straighten itself by geotropism, that is to say, the tip of the shoot began to curve upwards. I applied a delicate means of measuring this upward movement, and allowed it to continue for some time. I then turned the bottle round on its axis, so as to rest on what had been its upper surface, and the action of gravity being now reversed as far as the shoot went, the tip ought to have reversed its direction of growth, and curved upwards, but instead of this it went on curving towards the earth in consequence of the after-effect of the old stimulus. And it was more than an hour before it could reverse its movement, and again grow upwards.

With this case I conclude my comparison of plants and animals. Some of the points of resemblance which I have attempted to point out are purely analogical. Nevertheless, I have tried to show that a true relationship exists between the physiology of the two kingdoms. Until a man begins to work at plants, he is apt to grant to them the word "alive" in rather a meagre sense. But the more he works, the more vivid does the sense of their vitality become. The plant physiologist has much to learn from the worker who confines himself to animals. Possibly, however, the process may be partly reversed—it may be that from the study of plant-physiology we can learn something about the machinery of our own lives.

¹ Pfeffer, "Physiologische Unters.," 1873, p. 183.

² Pfeffer, "Physiologische Unters.," p. 195.

¹ Askenasy, *Bot. Zeitung*, 1877, No. 50, 51, 52; abstract *Naturforscher*, 1878, p. 44.

² Berthold, *Müll. Archiv*, 1837, p. 63.